Technical Appendix C

Derivation of Model Exposure Parameters

Table of Contents

1. Introduction

This appendix provides information on the data and methods used to derive subpopulation exposure parameters for use in the Indicators model. Three human exposure parameters (an inhalation rate, fish ingestion rate, and drinking water ingestion rate) and body weight are currently used in the RSEI model to generate sex-specific exposure factors for four age groups (ages ≤17, 18-44, 45-64, 65+). Earlier versions of the model used standard assumptions to represent intake for all individuals within the general population. However, because there are population-specific intake differences and because some populations may be more susceptible to certain chemicals than others, we have included subpopulation intake and census data in the model to estimate a more accurate surrogate dose.

2. Exposure Parameters

The most recent *Exposure Factors Handbook* (USEPA, 1997) is the primary source of information used to generate exposure parameters for both inhalation and drinking water ingestion. Fish consumption data was obtained directly from EPA's Office of Water (USEPA, 2000), based on an analysis of the 1994-1996 USDA Continuing Survey of Food Intake in Individuals (CSFII).

The exposure parameters were generated in such a way as to ensure as much consistency as possible among pathways, while basing the estimates on values recommended in the *Exposure Factors Handbook* (USEPA, 1997), when available. The parameters generally reflect those recommended in USEPA (1997), however, some estimates are derived from data in USEPA (1997) that were not explicitly included in their summarized recommendations.

The exposure factors in USEPA (1997) are available for a large number of discrete age groups, particularly for children. The RSEI age groups are generally broader than those in USEPA (1997). To match the RSEI age groups, we calculate an average of exposure factors for all ages within the RSEI age group. The algorithm is shown in Equation C-1. Intake rates are then adjusted by body weight estimates from USEPA (1997), when necessary. The sections below provide further detail on the calculation of pathway-specific exposure parameters.

Equation C-1

$$\text{RSEI Exposure Factors} = \frac{\sum_i (IR_i \times n_i)}{N}$$

where:

IR is the intake rate for age group *i*,
n is the number of years in age group *i*, and
N is the total number of years in the RSEI model age group

for all age groups *i* that fall within the RSEI age group.

2.1 Inhalation

Recommended mean inhalation values (m^3/day) for several children's age groups and adults were obtained from EPA's Exposure Factors Handbook (USEPA, 1997, Table 5-23, p. 5-24) and are presented in Table C-1. The EPA recommended inhalation values for adults (ages 19-65+) given in Table C-1 are based on the average of three different approaches presented in USEPA (1997, Tables 5-11 to 5-13). The inhalation rates for each of these approaches (food-energy intakes; ratios of total energy expenditure to basal metabolic rate (BMR); and time-activity survey) are presented in Table C-2.

Table C-1. EPA Recommended Inhalation Values[1]

Age Group (years)	Sex	Inhalation Values (m^3/day)
<1	Both	4.5
1-2	Both	6.8
3-5	Both	8.3
6-8	Both	10
9-11	Male	14
	Female	13
12-14	Male	15
	Female	12
15-18	Male	17
	Female	12
19-65+	Male	11.3
	Female	15.2

1. See USEPA (1997, Table 5-23, p.5-24).

Table C-2. Adult Inhalation Values Forming the Basis of EPA Recommended Values (m^3/day)

Based on food-energy intakes[1]			Based on total energy/BMR[2]			Based on time-activity data[3]		
Age	Male	Female	Age	Male	Female	Age	Male	Female
19-22	16	11	18-29	17	11	--	--	--
23-34	16	11	--	--	--	20-34	17	15
35-50	15	10	30-59	16	11	35-49	17	13
51-64	15	10	--	--	--	50-64	16	13
65-74	13	9.7	60+	13	9.9	65-74	13	11
75+	13	9.6	--	--	--	--	--	--

1. See USEPA (1997, Table 5-11, p. 5-13).
2. See USEPA (1997, Table 5-12, p. 5-14).
3. See USEPA (1997, Table 5-13, p. 5-15).

The inhalation values shown in Tables 1 and 2 were used to generate inhalation rates for the RSEI model age groups. We use Equation C-1 to calculate the RSEI inhalation values where IR (intake rate) is inhalation rate in m^3/day.

For the RSEI ≤17 year old age group, the relevant USEPA (1997) age groups are ages <1, 1-2, 3-5, 6-8, 9-11, 12-14, and 15-18 years old. In order to calculate the weighted average, the intake rate for age <1 is multiplied by 1, the intake rate for ages 1-2 is multiplied by 2, and so on. In this case, the intake rate for 15-18 year olds is multiplied by 3 because only 3 years (ages 15, 16, and 17) fall within the RSEI ≤17 year old age group. These products are then summed and divided by the total number of years in the RSEI age group, 18. The inhalation values and weights used to calculate the RSEI ≤17 year old male inhalation value are shown in Table C-3.

Table C-3. Calculation of RSEI ≤17 Year Old Male Inhalation Value (m^3/day)

Age Group	Inhalation Value (m^3/day)	Weight	Value x Weight
<1	4.5	1	4.5
1-2	6.8	2	13.6
3-5	8.3	3	24.9
6-8	10	3	30
9-11	14	3	42
12-14	15	3	45
15-18	17	3	51
			$\sum(IR_i \text{ x } n_i) = 211$

$$\text{RSEI} \leq 17 \text{ Year Old Male} = \sum \frac{(IR_i x n_i)}{N} = 211/18 = 11.7 \text{ m}^3\text{/day}$$

For adults, inhalation values were calculated for the RSEI age cohorts (18-44, 45-64, 65+) for each of the three alternative methods described in Table C-2. These three alternative inhalation values were then averaged to generate a single sex-specific inhalation value for each age group. The inhalation values generated for the RSEI age groups are shown in Table C-4.

Table C-4. Inhalation Values for Each RSEI Age Group

Model Age Group	Inhalation Value (m^3/day)*	
	Male	Female
0-17	11.7	10.2
18-44	16.4	12.0
45-64	15.5	11.2
65+	13.0	10.2

* See text for discussion of method used to calculate intake values.

For adults and children, the age and sex-specific inhalation values were adjusted by body weight using estimates recommended by EPA (USEPA, 1997, Tables 7-2 and 7-3, p. 7-4). USEPA (1997) provides estimates of mean body weight for boys and girls, for one-year age increments up to 19 years of age and for several adult age groups. Sex-specific body weights were averaged across the range of each RSEI age group and are presented in Table C-5. The final inhalation exposure factors used in the model are given in Table C-6.

Table C-5. Body Weights for Each RSEI Age Group from USEPA (1997)

Model Age Group	Body Weight (kg)	
	Male	Female
0-17	34.3	33.0
18-44	78.2	64.3
45-64	79.9	68.0
65+	74.8	66.6

Table C-6. Inhalation Exposure Factors Used in RSEI Model (m^3/kg-day)

Model Age Group	Male	Female
0-17	0.341	0.310
18-44	0.209	0.186
45-64	0.194	0.165
≥65	0.174	0.153

2.2 Drinking Water Ingestion

For children, EPA recommended mean tapwater intakes come from two key studies, Ershow and Cantor (1989) and the Canadian Ministry of National Health and Welfare (1981) (USEPA, Table 3-33, p.3-27). EPA recommends "using the Ershow and Cantor (1989) data in preference to the Canadian Ministry of National Health and Welfare (1981) data...where the age ranges overlap" (USEPA, 1997, p.3-27). More refined age-specific intakes for Ershow and Cantor (1989) were obtained from USEPA (1997, Table 3-6, p.3-5) and are presented in Table C-7.

Table C-7. Drinking Water Intake Values from Ershow and Cantor (1989)

Age Group (years)	Drinking Water Intake[1] (mL/kg-day)
<0.5	52.4
0.5-0.9	36.2
1-3	46.8
4-6	37.9
7-10	26.9
11-14	20.2
15-19	16.4
20-44	18.6
45-64	22
65-74	21.9
75+	21.6

1. Drinking water intakes are from USEPA (1997, Table 3-7, p.3-6).

Drinking water intake rates per body weight were calculated for each of the RSEI groups using Equation C-1, where IR (intake rate) is drinking water intake in L/kg-day. The final drinking water exposure factors are presented in Table C-8. Since body weight was already incorporated into the intake rates and sex-specific intake rates were not presented, the drinking water exposure factors are equivalent for males and females.

Table C-8. Drinking Water Exposure Factors Used in RSEI Model (L/kg-day)

Model Age Group	Male	Female
0-17	0.0298	0.0298
18-44	0.0184	0.0184
45-64	0.0220	0.0220
≥65	0.0219	0.0219

2.3 Fish Consumption

Data on fish consumption (g/day) by age group and gender were obtained directly from EPA's Office of Water (USEPA, 2000). The data is based on the 1994-1996 USDA Continuing Survey of Food Intake by Individuals (CSFII). Data on freshwater/estuarine fish consumption was available for three broad age groups: 14 and younger, 15-44 years old, and 45 and older. To estimate exposure parameters for recreational consumers, the 90th percentile of intake was used, while for subsistence consumers, the 99th percentile was chosen. Table C-9 shows the consumption values for recreational and subsistence consumers.

Table C-9. Fish Consumption Intake Data, CSFII 94-96

Age Group	Sex	Fish Consumption[1] (g/day)	
		Recreational	Subsistence
<15	Male	0.00	86.51
	Female	0.00	59.01
15-44	Male	15.57	150.20
	Female	7.36	109.72
45+	Male	32.47	165.92
	Female	17.78	108.80

1. Fish consumption data comes from USEPA (2000, Section 5.1.1.1, Table 1, p. 5-3). Data is based on the 1994-96 USDA Continuing Survey of Food Intakes by Individuals (CSFII). The 90th percentile is used to represent recreational consumers and 99th percentile is used to represent subsistence consumers.

To estimate fish ingestion values for the RSEI age groups, average intake rates were calculated using Equation C-1. For example, in order to calculate fish ingestion rates for the RSEI ≤17 year old age group, the intake rate for <15 year olds is multiplied by 15 and the intake rate for 15-44 year olds is multiplied by 3. These products are then summed and divided by the total number of years in the RSEI age group, 18. The ingestion rates and weights used to calculate the RSEI ≤17 year old male recreational fish ingestion value are shown in Table C-10.

Table C-10. Calculation of RSEI ≤17 Year Old Male Recreational Fish Ingestion Value (g/day)

Age Group	Recreational Fish Ingestion (g/day)	Weight	Value x Weight
<15	0.00	15	0.00
15-44	15.57	3	46.71
			$\sum(IR_i \times n_i) = 46.71$

$$\text{RSEI} \leq 17 \text{ Year Old Male} = \sum \frac{(IR_i \, xn_i)}{N} = 46.71/18 = 2.60 \text{ g/day}$$

The fish ingestion intakes and body weights for each of the model age groups are presented in Table C-11. The corresponding fish ingestion exposure factors used in the RSEI model are shown in Table C-12.

Table C-11. Fish Ingestion Values and Body Weights for Each RSEI Age Group from USEPA (2000) and USEPA (1997)

Model Age Group	Recreational Fish Ingestion (g/day)*		Subsistence Fish Ingestion (g/day)*		Body Weight (kg)	
	Male	Female	Male	Female	Male	Female
0-17	2.60	1.23	97.1	67.5	34.3	33.0
18-44	15.6	7.36	150	110	78.2	64.3
45-64	32.5	17.8	166	109	79.9	68.0
65+	32.5	17.8	166	109	74.8	66.6

* See text for discussion of method used to calculate ingestion values.

Table C-12. Fish Ingestion Exposure Factors Used in RSEI Model

	Recreational (g/kg-day)*		Subsistence (g/kg-day)*	
Model Age Group	Male	Female	Male	Female
0-17	0.0756	0.0372	2.83	2.05
18-44	0.199	0.114	1.92	1.71
45-64	0.407	0.262	2.08	1.60
≥65	0.434	0.267	2.22	1.63

* Fish ingestion exposure factors are converted to kg/kg-day for the surrogate dose calculation in the RSEI model.

3. References

Canadian Ministry of National Health and Welfare. 1981. *Tapwater Consumption in Canada.* Doc # 82-EHD-80. Public Affairs Directorate, Department of National Health and Welfare, Ottawa, Canada.

Ershow AG and Cantor KP. 1989. *Total Water and Tapwater Intake in the United States: Population-Based Estimates of Quantities and Sources.* Life Sciences Research Office, Federation of American Societies for Experimental Biology.

National Center for Health Statistics (NCHS, 1987. *Anthropometric Reference Data and Prevalence of Overweight, United States*, 1976-80. Data from the National Health and Nutrition Examination Survey, Series 11, No. 238. U.S. Department of Health and Human Services, Public Health Service, National Center for Health Statistics. DHHS Publication No. (PHS) 87-1688.

U.S. Environmental Protection Agency (USEPA, 1997). *Exposure Factors Handbook.* Office of Health and Environmental Assessment. Volumes 1 and 2. EPA/600/P-95/002Fa and EPA/600/P-95/002Fb.

U.S. Environmental Protection Agency (USEPA, 2000). *Estimated Per Capita Fish Consumption in the United States.* Office of Water and Office of Science and Technology.